Investigation

CRANK IT UP!

Background Information

Most internal-combustion engines are of the reciprocating type. Reciprocating engines are powered by pistons that move back and forth inside enclosed cylinders. The reciprocating motion of the pistons is then converted to rotary motion by a crankshaft to perform useful work such as turning the wheels of a car or truck.

In a four-cycle engine, the piston makes two trips up and two trips down the cylinder during each cycle. The four cycles are the intake, compression, power and exhaust strokes.

Intake stroke. The piston moves down in the cylinder with the intake valve open, sucking a combustible mixture of air and fuel through the valve into the cylinder. The intake valve closes, sealing the mixture in the cylinder.

Compression stroke. The piston then moves up with both intake and exhaust valves closed, compressing the air-fuel mixture to a fraction of the total cylinder volume in a small space in the cylinder head called the combustion chamber. The ratio of total cylinder volume to combustion-chamber volume is the engine's compression ratio, typically 8.5:1 or 9:1 for a spark-ignited (gasoline or alternative-fuel) engine.

Power stroke. In a spark-ignition engine, a spark plug protrudes into the combustion chamber. At the point of greatest compression, a precisely timed electrical current jumps across the gap between the two electrodes of the spark plug, igniting the surrounding air-fuel mixture. The mixture explodes, its chemical energy changing rapidly into heat energy. The temperature of the air and the air pressure inside the combustion chamber rise rapidly, pushing down on the piston with great force.

In a compression-ignition (diesel) engine, the air-fuel mixture is compressed so much (up to 20:1 compression ratio) that it ignites spontaneously, without a spark plug.

Exhaust stroke. The piston moves up with the intake valve closed and the exhaust valve open, pushing the burned air-fuel mixture out of the cylinder into the exhaust manifold. The exhaust valve closes and the intake valve opens to begin the cycle again.

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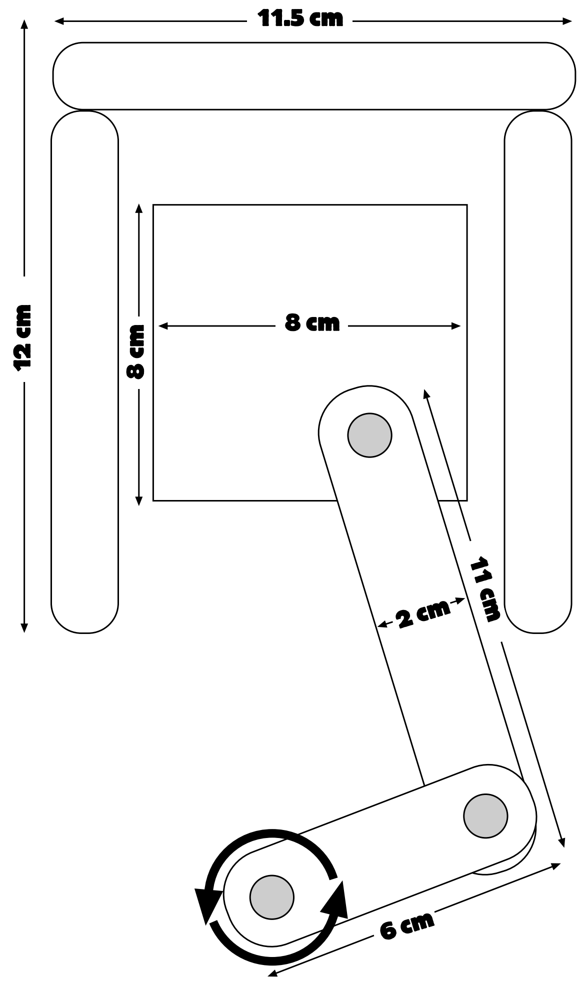
The size of engine cylinders varies; however, most spark-ignited engines have about an 8:1 compression ratio. This means that the volume of the cylinder when the piston is at the bottom of its stroke is eight times the volume at the top of the stroke. In other words, the compression ratio is the maximum volume divided by the minimum volume of the cylinder.

Higher compression ratios usually provide better efficiency, but engineers must consider many other factors in designing engines. Among these are suitability for a particular task, engine materials, and cost.

In this activity you will build a model piston/crankshaft system to demonstrate how a four-cycle engine transfers energy and changes reciprocating motion to rotary motion. You will also compare compression ratios for different fuels.



Materials

6 popsicle sticks 4 brads
scissors glue
1 piece of cardboard 16 cm x 16 cm
1 piece of cardboard 8 1/2 cm x 11 cm

Procedure

1. Form the outline of a cylinder with three popsicle sticks by gluing them to the bottom edge of the 16 cm x 16 cm piece of cardboard.
2. Glue the other popsicle sticks on top of the first three popsicle sticks.
3. Cut an 8 cm x 8 cm square from the other piece of cardboard to represent the piston.
4. Cut an 11 cm x 2 cm strip and a 6 x 2 cm strip.
5. Poke a hole in the end of each strip.
6. Attach one end of the strip (the piston connecting rod and crankshaft) together with a brad.
7. Poke a hole in the piston and attach the other end of the piston rod. Allow enough room so that the piston rod can turn the crankshaft completely when the piston head moves up and down.

8. Put the last brad halfway through the second hole in the crankshaft and flatten the ends of the brad. This should make a knob, which can be used to turn the crankshaft.

Observations

1. Begin with the piston at the top of the cylinder. Holding onto the knob, gently rotate the crankshaft. What happened to the piston when the crankshaft was rotated?

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2. This represents which stroke? ______________________________

3. Holding onto the knob, gently rotate the crankshaft again. What happened to the piston when the crankshaft was rotated? ______________________________

4. This represents which stroke? ______________________________

5. Describe the next stroke in a four-cycle engine. ______________________________

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6. Using the model, demonstrate the third stroke of the engine and describe the position of the piston in the cylinder. ______________________________

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7. Holding onto the knob, gently rotate the crankshaft again. What happened to the piston when the crankshaft was rotated? ______________________________

8. This represents which stroke? ______________________________

9. What is the purpose of the motion of the crankshaft? ______________________________

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10. What process that occurs in an engine is missing from this piston/crankshaft model? ________

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Conclusion

1. Explain how chemical energy in the cylinder is changed into heat energy.

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2. Explain how heat energy is converted into mechanical energy. ______________________________

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3. Explain how the linear motion of the piston is converted into the rotary motion of the wheels. ______________________________

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Application

1. How does the motion of an automobile engine compare with the movement of a steam locomotive engine? ______________________________

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2. The size of each cylinder in a car engine can be determined by dividing the engine's total displacement, in cubic inches or liters, by the number of cylinders. If a 4.0-liter car had six cylinders, what would be the volume of each cylinder? ______________________________

3. Assume that a gasoline engine has a compression ratio of 8:1. This would mean that the air-fuel mixture is compressed to one-eighth its original volume. If the original volume of gas was 1.3 liters, what would the compressed volume be? ______________________________

4. A propane engine has a compression ratio of 10:1. If the original volume of gas was 1.3 liters, what would the compressed volume be? ______________________________

5. A natural gas engine has a compression ratio of 11:1. If the original volume of gas was 1.3 liters, what would the compressed volume be? ______________________________

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Going Further

1. Assume the three fuels above were used in engines with compression ratios of 8:1. Which fuel would perform most efficiently? ______________________________

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2. As an automotive engineer, what would you do to make sure that engines using alternative fuels maintained as high an efficiency rating as possible?

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